

METHOD AND APPARATUS FOR THE DISTRIBUTION AND ENHANCEMENT OF  
DIGITAL COMPRESSED AUDIO

Invented by

David W. Runton

a resident of

1666 West Bluebird Drive  
Chandler, Arizona 85248

and

Peter A. Smith

a resident of

1416 West Lark Drive  
Chandler, Arizona 85248

both citizens of  
the United States

1 METHOD AND APPARATUS FOR THE DISTRIBUTION  
2 AND  
3 ENHANCEMENT OF DIGITAL COMPRESSED AUDIO  
4  
5

6 FIELD OF THE INVENTION  
7

8 This invention relates to methods and apparatus for  
9 distributing and enhancing sound which was digitally  
10 compressed and then decompressed.

11  
12 More particularly, the present invention relates to  
13 apparatus for reconstructing lost audio which has been  
14 digitally compressed and decompressed.

15  
16 In a further and more specific aspect, the instant  
17 invention concerns methods of distributing to consumers  
18 reconstructed lost audio which has been digitally  
19 compressed and decompressed.

## BACKGROUND OF THE INVENTION

The distribution of digital audio through the world wide web (Internet) requires a significant amount of data compression. A compact disc (CD) quality song recorded in stereo requires nearly 10 MB of data per minute. Utilizing existing transfer methods available to the typical home user, this amount of data is considered unusable. To combat this, the Internet community has developed several different compression techniques for reducing the amount of data required to construct the audio signal. At the compression requirements, these algorithms are not perfect, resulting in loss of the data and subsequent audio quality degradation.

A specific compression/decompression algorithm is based on MPEG 1, audio layer 3, and is commonly referred to as MP3. An MP3 formatted file contains audio data that has been processed through a compression algorithm. The file can be stored on a computer hard drive, floppy disk, or any other storage medium such as flash RAM cards. The MP3 file format was developed to compress the large amounts of data stored on music CDs to less than one tenth of the original size of the data. The compressed data can then easily be sent over the Internet or stored on computer hard drives, etc. The major problem that arises is in the quality of music that has been compressed and then decompressed for

1 listening.

2

3       Even though some enhancement is performed during the  
4 decompression of the data in an attempt to reconstruct the  
5 music, many of the qualities that make the music  
6 interesting or enjoyable are lost. Further, because of the  
7 lost data during compression/decompression, the  
8 compression/decompression technique cannot be used in many  
9 other fields where the lost data may be important (e.g.  
10 some teaching techniques, such as speech and listening  
11 therapy). Many different attempts to enhance music to  
12 improve the quality have been made in the past but each  
13 such attempt is directed at a specific problem (generally  
14 the attempt deals with improving the response of a specific  
15 amplifier) and generally requires specific hardware to  
16 solve, or partially solve, the specific problem. Also,  
17 because in many instances individuals are receiving the  
18 data or music from the Internet, it is difficult to provide  
19 a salable technique for improving the decompressed data.

20

21       Accordingly, it is an object of the present invention  
22 to provide new and improved methods and apparatus/software  
23 for the distribution and enhancement of digital  
24 compressed/decompressed audio.

25

26       Another object of the invention is to provide new and  
27 improved apparatus/software for restoring decompressed data

1 to substantially its original content.

2

3 And another object of the invention is to provide new  
4 and improved apparatus/software for restoring decompressed  
5 data to substantially its original content, which apparatus  
6 itself can be sold over the Internet or by equivalent  
7 means.

8

9 Still another object of the present invention is to  
10 provide new and improved methods for distributing the  
11 apparatus software.

12

13 Yet another object of the invention is to provide new  
14 and improved methods of distribution for the  
15 apparatus/software which provide a recipient the  
16 opportunity to try the apparatus software and determine if  
17 they believe it is appropriate for them.

## SUMMARY OF THE INVENTION

Briefly, to achieve the desired objects of the instant invention in accordance with a preferred embodiment thereof apparatus for enhancing digital audio signals after the digital audio signals are compressed and decompressed is provided. The apparatus includes an input terminal for receiving a digital decompressed audio signal, a digital harmonic enhancer coupled to receive the digital decompressed audio signal and provide a harmonically enhanced audio signal, a digital warmth adder coupled to receive the digital decompressed audio signal and provide a warmth enhanced audio signal, and a digital frequency equalizer coupled to receive the harmonically enhanced audio signal and the warmth enhanced audio signal and provide a digital enhanced decompressed audio signal. In a preferred embodiment the apparatus is provided in the form of software as instructions for a Digital Signal Processor (DSP) or the like.

The desired objects of the instant invention are also achieved in accordance with a preferred embodiment thereof in method of enhancing digital audio signals after the digital audio signals are compressed and decompressed. The method includes the steps of receiving a digital decompressed audio signal, harmonically enhancing the digital decompressed audio signal and providing a

1 harmonically enhanced audio signal, adding warmth to the  
2 digital decompressed audio signal and providing a warmth  
3 enhanced audio signal, and combining and frequency  
4 equalizing the harmonically enhanced audio signal and the  
5 warmth enhanced audio signal to provide a digital enhanced  
6 decompressed audio signal. Warmth, in the present context,  
7 is harmonic content considered pleasant to the ear, and is  
8 usually associated with enhanced odd order harmonics.

9

10 The desired objects of the instant invention are also  
11 achieved in accordance with a preferred embodiment thereof  
12 in method of distributing enhanced digital audio signals  
13 produced from compressed and decompressed digital audio  
14 signals. The distribution method includes the steps of  
15 providing software for a digital signal processor including  
16 harmonically enhancing the digital decompressed audio  
17 signal to provide a harmonically enhanced audio signal,  
18 adding warmth to the digital decompressed audio signal to  
19 provide a warmth enhanced audio signal, and combining and  
20 frequency equalizing the harmonically enhanced audio signal  
21 and the warmth enhanced audio signal to provide a digital  
22 enhanced decompressed audio signal, and providing  
23 adjustments within the software for varying levels of the  
24 harmonic enhancing and for varying levels of the frequency  
25 equalizing to provide the digital enhanced decompressed  
26 audio signal.

1 In one specific embodiment of the distribution  
2 procedure the software is provided free and either a one-  
3 time use, a partial use, a partially enhanced audio signal  
4 use, or non-save adjustments are included in the software  
5 to limit the use. The software is then sold for a price  
6 without including in the software the one-time use, the  
7 partial use, the partially enhanced audio signal use, or  
8 the non-save adjustments.

9

10 In another specific embodiment of the distribution  
11 procedure adjustments are provided within the software for  
12 varying levels of the harmonic enhancing and for varying  
13 levels of frequency equalizing to provide the digital  
14 enhanced decompressed audio signal, the adjustments are  
15 preset to levels determined by an expert of the received  
16 digital decompressed audio signal, such as a performer of  
17 music. In this fashion the user hears the music as the  
18 performer wants it to be heard. This method of  
19 distribution is a subset of mass customization, i.e. the  
20 software can be adjusted by the originator or consumer to  
21 tailor the desired sound.



BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and further and more specific objects and advantages of the instant invention will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiment thereof taken in conjunction with the drawings, in which:

FIG. 1 is a block diagram of signal processing apparatus/software for enhancing digital audio signals after the digital audio signals are compressed and decompressed;

FIG. 2 is a more detailed block diagram of a harmonic enhancer portion of the signal processing apparatus of FIG. 1;

FIG. 3 illustrates a response curve for a prior art transistor amplifier;

FIG. 4 illustrates a response curve for the warmth adder of FIG. 1;

FIG. 5 is a typical frequency spectrum for the human ear, illustrating the effects of the frequency equalizer of FIG. 1; and

[illegible]

1 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

2

3 Turning now to the drawings in which like reference  
4 characters indicate corresponding elements throughout the  
5 several views, attention is first directed to FIG. 1 which  
6 illustrates a block diagram of signal processing  
7 apparatus/software 10 for enhancing digital audio signals  
8 after the digital audio signals are compressed and  
9 decompressed. Digital audio signals, which have been  
10 compressed and decompressed by some format or software,  
11 such as MP3, are received at an input terminal 11. The  
12 input digital audio signal is split and applied  
13 simultaneously to both a harmonic enhancer 12 and a warmth  
14 adder 15.

15

16 Referring additionally to FIG. 2, a more detailed  
17 block diagram of harmonic enhancer 12 is illustrated. The  
18 digital audio signal supplied to harmonic enhancer 12 is  
19 again split and applied to a digital hi-pass filter 20 and  
20 to one input of a digital adder 21. Hi-pass filter 20 has  
21 a specific bandpass and includes a frequency adjustment 23  
22 which moves the bandpass of filter 20 to determines a  
23 specific band of frequencies within the input digital audio  
24 signal which will be passed by hi-pass filter 20.

25

26 The portion of the input digital audio signal passed  
27 by digital hi-pass filter 20 is supplied to a digital

1 amplifier 25 coupled to provide harmonic distortion.  
2 Amplifier 25 is constructed to drive the input signal into  
3 saturation so as to provide an at least partially squared  
4 audio signal. This partially squared audio signal contains  
5 harmonics, both odd and even, and the amount of squaring,  
6 or saturation amplification, determines the specific  
7 harmonics included (i.e. second, third, fourth, fifth,  
8 etc.), as well as the amount of harmonics included in the  
9 output signal. As an example, an audio signal that is only  
10 slightly distorted by amplification into the saturation  
11 area (i.e. squared) contains only small amounts of the  
12 second and third harmonics. As the amplification is  
13 increased both the amount of the harmonics and the number  
14 of harmonics increases. Since, for example, most music  
15 contains certain harmonics and since some of these  
16 harmonics are lost during the compression/decompression  
17 process, it is important to achieve natural and pleasant  
18 sounding music that the harmonics be reconstructed after  
19 the decompression process. As can be seen from FIG. 2,  
20 only the portion of the digital audio signal passed by hi-  
21 pass filter 20 is amplified by amplifier 25 to provide a  
22 harmonic enhancement signal.

23

24 The harmonic enhancement signal from amplifier 25 is  
25 then supplied to a digital level adjuster 26 which provides  
26 a level adjusted harmonic enhancement signal to a second  
27 input of digital adder 21. Level adjuster 26 is provided

1 with an adjustment 27 which determines the amount, or level  
2 of the harmonic enhancement signal that is applied to adder  
3 21. Since the original digital audio signal supplied to  
4 input terminal 11 is supplied to one input of adder 21, the  
5 selected level of the harmonic enhancement signal that is  
6 applied to the other input of adder 21 is added to the  
7 original digital audio signal to provide a harmonically  
8 enhanced digital audio signal. Here it should be noted  
9 that frequency adjustment 23 of hi-pass filter 20  
10 determines the frequency spectrum of the harmonic  
11 enhancement while adjustment 27 provides the level of the  
12 harmonic enhancement.

13

14 Referring specifically to FIG. 3, a typical response  
15 curve 30 for a transistor amplifier is illustrated. As can  
16 be seen, response curve 30 includes relatively sharp  
17 discontinuities at a positive saturation area 31 and at a  
18 negative saturation area 32. Discontinuities 31 and 32  
19 produce some harsh and relatively unpleasant sounds in  
20 audio that is amplified to this level and, accordingly,  
21 transistor amplifiers are generally only used for  
22 amplification in the linear range of response curve 30.

23

24 Electronic tubes, on the other hand, have a response  
25 curve similar to curve 35 illustrated in FIG. 4.. As can be  
26 seen, curve 35 is rounded or continuous and blends smoothly  
27 at upper and lower saturation areas 36 and 37 from the

1 linear portion of curve 35 into the saturated portion.  
2 This smooth blending produces harmonics which add warmth  
3 to, for example, music and is a major reason that  
4 electronic tube amplifiers are preferred in the music field  
5 over transistor amplifiers. Referring to FIG. 1, warmth  
6 adder 15 includes a digital saturation amplifier in which  
7 the amplification is specifically adjusted to resemble  
8 curve 35 of FIG. 4. For purposes of this disclosure, the  
9 response curve of warmth adder 15 will hereinafter be  
10 referred to as an S-shaped response curve or a response  
11 curve that includes upper and lower saturation areas which  
12 are rounded (smoothed or continuous) to provide warmth  
13 distortion or a warmth enhanced digital audio signal.

14  
15 Turning again to FIG. 1, the harmonically enhanced  
16 digital audio signal from harmonic enhancer 12 and the  
17 warmth enhanced digital audio signal from warmth adder 15  
18 are combined and supplied to a digital frequency equalizer  
19 40. Illustrated in FIG. 5 is a typical frequency spectrum  
20 42 for the human ear. Although there are many variations,  
21 weaknesses and strengths, a typical human ear can generally  
22 hear sounds from 20 Hz to 20 kHz. Frequency equalizer 40  
23 breaks frequency spectrum 42 into a plurality of areas, for  
24 example, the three areas 44, 45, and 46 illustrated in FIG.  
25 6. Here it should be understood that many more areas could  
26 be included or each area 44, 45, and 46 could be again  
27 split into a plurality of sub-areas. In this discussion

1 area 44 is referred to as a base area, area 45 is referred  
2 to as a midrange area, and area 46 is referred to as a  
3 treble area.

4

5 Frequency equalizer 40 can include any or all of  
6 digital filters, generally for splitting frequency spectrum  
7 40 into areas 44, 45, and 46, digital amplifiers for  
8 amplifying the frequency spectrum represented by each of  
9 the areas 44, 45, and 46, and attenuators for reducing the  
10 frequency spectrum represented by each of the areas 44, 45,  
11 and 46. Further, frequency equalizer 40 includes  
12 adjustments for each of the areas 44, 45, and 46 to alter  
13 the frequency spectrum or response for that area anywhere  
14 between amplification and attenuation. Referring to FIG.  
15 5, as an example, a curve 48 illustrates a level of  
16 amplification in treble area 46 and a curve 49 illustrates  
17 a level of attenuation in treble area 46. The adjustment  
18 for treble area 46 is capable of changing the response  
19 curve anywhere from curve 48 to curve 49 and in a similar  
20 fashion each of the other areas can be changed.

21

22 Standard Digital Signal Processing, or DSP, is used to  
23 digitally modify incoming digital data to produce a desired  
24 output. Utilizing these techniques, it is possible to  
25 simulate any analog circuitry (including filters,  
26 amplifiers, adders, attenuators, etc.). The notation used  
27 for the DSP is:

1         $x[n] \rightarrow H_T(e^{j\omega}) \rightarrow y[n]$

2

3        In the above notation,  $x[n]$  is the input signal which  
4 is sampled in discrete time intervals,  $H_T(e^{j\omega})$  is the  
5 processing algorithm, and  $y[n]$  is the output signal.  
6 Signal processing apparatus/software 10, described above,  
7 including harmonic enhancer 12, warmth adder 15, and  
8 frequency equalizer 40, are included in software in the  
9 form of instructions to a DSP which instructs the DSP to  
10 perform the various steps described. Typically, the  
11 software, or instructions, are included on some form of  
12 memory, such as a CD, or can be downloaded from the  
13 Internet to a personal computer (PC) or some other type of  
14 equipment containing a DSP or performing DSP functions.  
15 Here it should be understood by those skilled in the art  
16 that the term "Digital Signal Processor" (DSP), as used in  
17 this disclosure, includes chips and devices designated  
18 digital signal processors as well as any other devices  
19 which are capable of performing the function of digital  
20 signal processing

21

22        Further, frequency adjust 23 for hi-pass filter 20,  
23 adjustment 27 for digital level adjuster 26, and parameter  
24 presets, or adjustments, for frequency equalizer 40 are  
25 included in the software and instruct the DSP to provide  
26 these adjustments on the PC, etc. in the same fashion that  
27 such adjustments are presently provided on a PC. In an



1 alternative embodiment, these adjustments can be preset.  
2 For example, a specific piece (or album) of music might be  
3 supplied with preset parameters that adjust signal  
4 processing apparatus/software 10 in accordance with the way  
5 an expert, such as the performer of the music, would like  
6 their music to sound.

7

8 In a typical example of the use of signal processing  
9 apparatus/software 10, a person would download signal  
10 processing apparatus/software 10 from the Internet into  
11 their PC and would then either play compressed music  
12 directly from the Internet or from the hard disk of their  
13 computer, using signal processing apparatus/software 10. A  
14 problem that arises with the provision of this type of  
15 signal processing apparatus/software is the distribution,  
16 since the software can be easily downloaded from the  
17 Internet or from a CD or the like by anyone.

18

19 One distribution system that is used herein to  
20 overcome this problem is to provide adjustments within the  
21 software for varying levels of the harmonic enhancing and  
22 for varying levels of the frequency equalizing to provide  
23 the digital enhanced decompressed audio signal and provide  
24 the software free to any and all recipients. However, the  
25 free software is programmed for a one-time use, a partial  
26 use, a partially enhanced audio signal use, or non-save  
27 adjustments. A one-time use is one in which the recipient

1 can play the audio once to appreciate the improved sound  
2 and then must get another copy of signal processing  
3 apparatus/software 10. A partial use is one in which the  
4 recipient can play only a part of the audio with the  
5 improved sound and after that the sound is the same as  
6 standard decompressed audio. A partially enhanced use is  
7 one in which some of the improvements in sound are included  
8 but not all of them simultaneously. Non-save adjustments  
9 is one in which the recipient must make all of the  
10 adjustments each time that he uses the software. After the  
11 recipient has used the free software he can purchase a copy  
12 for a price, which purchased copy does not include the one  
13 of the one-time use, the partial use, the partially  
14 enhanced audio signal use, or the non-save adjustments but  
15 which does include the entire signal processing  
16 apparatus/software 10 with savable presets.

17  
18 In another distribution system that is used herein to  
19 overcome the above described problem, the various  
20 adjustments are preset by someone who is an expert of that  
21 type of audio. For example, a performer who made a  
22 particular piece or album of music might set the various  
23 adjustments to make the music sound exactly as they want it  
24 to sound. These adjustments would then be included as  
25 presets in a specific copy of signal processing  
26 apparatus/software 10. Copies of signal processing  
27 apparatus/software 10 including the presets are then sold

1 with compressed music (MP3 or the like).

2

3       Accordingly, new and improved methods and apparatus  
4 for the distribution and enhancement of digital compressed  
5 audio have been disclosed.       The new and improved  
6 apparatus/software restores decompressed data to  
7 substantially its original content and can be sold over the  
8 Internet or by equivalent means.       Further, various methods  
9 for distributing the new and improved apparatus/software  
10 are disclosed which provide recipients an opportunity to  
11 sample the software and determine whether or not they  
12 believe they would like to purchase it.

13

14       Various changes and modifications to the embodiments  
15 herein chosen for purposes of illustration will readily  
16 occur to those skilled in the art.       To the extent that such  
17 modifications and variations do not depart from the spirit  
18 of the invention, they are intended to be included within  
19 the scope thereof which is assessed only by a fair  
20 interpretation of the following claims.

21

22       Having fully described the invention in such clear and  
23 concise terms as to enable those skilled in the art to  
24 understand and practice the same, the invention claimed is: